# Section 6: Commentary
# SEISMIC DESIGN REQUIREMENTS (SDR) 1 AND 2

## C6.2 DESIGN FORCES

In areas of low seismicity only minimum seat widths (Article 6.3) and connection design forces for bearings and minimum shear reinforcement in concrete columns and piles in SDR 2 are deemed necessary for the life safety performance objective. These default values are used as minimum design forces in lieu of rigorous analysis. The division of SDAP A1 and A2 at a short period spectral response acceleration of 0.10 is an arbitrary expedience intended to provide some relief to parts of the country with very low seismicity.

This article describes the minimum connection force that must be transferred from the superstructure to its supporting substructures through the bearings. It does not apply if the connection is a monolithic structural joint. Similarly, it does not apply to unrestrained bearings or in the unrestrained directions of bearings that are free to move (slide) in one direction but fixed (restrained) in an orthogonal direction. If a bridge has all elastomerics or all sliders then either these minimums apply to all bearing connections or the forces shall be determined using the provisions of Article 6.10. The minimum force is simply 0.1 or 0.25 times the weight that is effective in the restrained direction. The calculation of the effective weight requires care and may be thought of as a tributary weight. It is calculated from the length of superstructure that is tributary to the bearing in the direction under consideration. For example, in the longitudinal direction at a fixed bearing, this length will be the length of the segment and may include more than one span if it is a continuous girder (i.e. it is the length from one expansion joint to the next). But in the transverse direction at the same bearing, this length may be as little as one-half of the span, particularly if it is supporting an expansion joint. This is because the expansion bearings at the adjacent piers will generally be transversely restrained and able to transfer lateral loads to the substructure.

It is important that not only the bearing but also the details that fasten the bearing to the sole and masonry plates (including the anchor bolts which engage the supporting members), have sufficient capacity to resist the above forces. At a fixed bearing, it is necessary to consider the simultaneous application of the longitudinal and transverse connection forces when checking these capacities.

Note that the primary purpose of this requirement is to ensure that the connections between the superstructure and its supporting substructures remain intact during the design earthquake and thus protect the girders from being unseated. The failure of these connections has been observed in many earthquakes and imposing minimum strength requirements is considered to be a simple but effective strategy to minimize the risk of collapse. However, in low seismic zones it is not necessary to design the substructures or their foundations for these forces since it is expected that if a column does yield it will have sufficient inherent ductility to survive without collapse. Even though bridge columns in SDR 2 are not required to be designed for seismic loads, shear reinforcement requirements will provide a minimum level of capacity for ductile deformations which is considered to be adequate for the magnitude and duration of the ground motion expected in SDR 2.

The magnitude of live load assumed to exist at the time of the earthquake should be consistent with the value of $\gamma_{eq}$ used in conjunction with Table 3.4.1-1.

## C6.3 DESIGN DISPLACEMENTS

Unseating of girders at abutments and piers must be avoided in all circumstances. The current Division I-A requirement for minimum seat width is:

$$N = 0.20 + 0.0017L + 0.0067H$$

for seismic performance catergories A and B. The seat width is multiplied by 1.5 for SPC C and

D. The seat width is further multiplied by 1/cosα to account for skew effects. The current expression gives reasonable minimum seat widths, but it is modified herein for higher seismic zones.

The requirement for minimum seat width accounts for (1) relative displacement due to out-of-phase ground motion of the piers, (2) rotation of pier footings, and (3) longitudinal and transverse deformation of the pier. The current expression provides reasonable estimates of the first two effects, but underestimates the third. The maximum deformation demand is given by the P–Δ limitation because P–Δ generally controls the displacement of the piers. The capacity spectrum gives:

$$C_c\Delta = \left(\frac{F_v S_1}{2\pi B}\right)^2 g$$

and the P–Δ limitation is:

$$C_c > 4\frac{\Delta}{H}$$

Combining the two expressions gives the maximum displacement when P–Δ controls:

$$\Delta = \frac{\sqrt{g}}{4\pi B}\sqrt{H}\cdot F_v S_1$$

Assuming $B$=1.4, with moderate ductility capacity, the longitudinal displacement limit in meter units is $\Delta_S = 0.18\sqrt{H}\cdot F_v S_1$.

Transverse displacement of a pier supporting a span with fixed bearing and a span with a longitidinal release will result in additional seat displacement. The seat displacement at the edge of the span with the longitudinal release is $2\Delta_S B/L$. Combining the seat displacement due to longitudinal and transverse displacement of the pier using the SRSS combination rule gives the pier displacement contribution to seat width as:

$$N = 0.18\sqrt{H}\sqrt{1+\left(2\frac{B}{L}\right)^2}\cdot F_v S_1$$

For $F_v S_1 = 0.40$ the coefficent is 0.072. Because transverse displacement of a pier is limited by "arching" of the superstructure, the maximum of B/L=3/8 is reasonable for determing the seat displacement.

Using this approach, the minimum seat width in Equation 6.3-1 is a linear function of the seismic hazard, $F_v S_1$. The factor on seat width varies from unity for $F_v S_1 = 0$ to 1.5 for $F_v S_1 = 0.40$. The factor for $F_v S_1 = 0.80$ is 2.0. The coefficient for the pier deformation term provides a contribution to the seat width for $F_v S_1 = 0.40$ of:

$$N = 0.075\sqrt{H}\sqrt{1+\left(2\frac{B}{L}\right)^2}$$

which is close the to value from the the P-Δ analysis. The constant term is reduced from 0.20 to 0.10 because the pier deformation is included directly.

Equation 6.3-1 provides seat width that are slightly larger than the Division I-A requirement for low seismic zones and larger seat widths for $F_v S_1 = 0.80$ are larger by a factor of 1.5 to 1.8.

## C6.7 STRUCTURAL STEEL DESIGN REQUIREMENTS

### C6.7.2 SDR 2

#### C6.7.2.1 Ductile Moment-Resisting Frames and Bents

##### *C6.7.2.1.1 Columns*

This is an arbitrary increase in the permitted maximum axial load, due to the lower ductility demands expected in SDR 2.

#### C6.7.2.3 Concentrically Braced Frames and Bents with Nominal Ductility

This is an arbitrary increase in the permitted maximum axial load, due to the lower ductility demands expected in SDR 2.